# FROTH-FLOTATION PRACTICE IN COAL-PREPARATION PLANTS OF WESTERN EUROPE AND GREAT BRITAIN

BY B. W. GANDRUD, THOMAS FRASER, AND H. F. YANCEY

* * * * * * * * * **Information Circular 7614**

MARCH 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

---

Work on manuscript completed April 1951. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7614."

July 1951

# FROTH-FLOTATION PRACTICE IN COAL-PREPARATION PLANTS OF WESTERN EUROPE AND GREAT BRITAIN

by

B. W. Gandrud,[1] Thomas Fraser,[2] and H. F. Yancey[3]

## CONTENTS

| | Page |
|---|---|
| Introduction and summary | 1 |
| Current froth-flotation practice on the continent | 4 |
|   Dutch State Mines | 4 |
|     Water clarification | 5 |
|   Western Germany | 6 |
|   New developments in froth-flotation equipment and techniques in Germany | 6 |
|     Flotation of coarse-grain coal | 6 |
|     Dewatering of fine coal in centrifuges; the Escher Wyss batch-type centrifuge and the centrifuge of Siebtechnik A. G. | 7 |
| Froth-flotation practice in Great Britain | 8 |
|   Operating data from individual plants | 9 |
|   Costs and power requirements | 15 |
|   Noticeable differences between froth-flotation practice in Great Britain and the United States | 16 |

---

[1] Chief, Fuels Technology Division, Region VII.
[2] Coal Technologist, Bureau of Mines, Washington, D. C.
[3] Chief, Fuels Technology Division, Region II.

## TABLES

Page

1. Summary of plants and of salient plant data .......... 3
2. Summary of operating data at the Dutch State Mines ... 5
3. Screen and ash analyses (dry basis) of flotation products at Dean and Chapter and Mainsforth ............ 10
4. Screen and ash analyses (dry basis) of flotation products at Grimethorpe ............................... 11
5. Screen and ash analyses (dry basis) of flotation products at Bentley ................................... 12
6. Screen analyses of flotation products at Denby Hall .. 13
7. Screen analyses of flotation products at Windsor ..... 14
8. Screen analyses of flotation products at Middle Duffryn ........................................ 15
9. Flotation-plant operating costs per ton of feed; maximums, minimums, and averages for the seven plants ........................................ 15

## ILLUSTRATIONS

Follows page

Fig.
1. Section through Kleinbentinck flotation cell .... 4
2. Series arrangement of Kleinbentinck flotation cells ........................................ 4
3. Scraper-type Escher Wyss centrifuge ............ 6
4. Sectional views showing the 3-cycle operation of the Escher Wyss centrifuge .................... 6
5. Sketch showing origin of flotation-cell feed at Dean and Chapter, and Mainsforth plants ....... 8
6. Flow sheet at Windsor plant ..................... 12
7. Froth flotation flow sheet at the Middle Duffryn plant ........................................ 14

# INTRODUCTION AND SUMMARY

In the summer of 1950, Bureau of Mines engineers visited a number of coal-preparation plants in western Europe and Great Britain to obtain information on European and British coal-cleaning and froth-flotation practices. In view of the growing importance of froth flotation as a process for cleaning fine sizes of coal, it was felt that such data and information would be of value in this country, for, although froth flotation has been adopted for use in a few of our plants, it has not as yet been employed as extensively as in British and European preparation plants.

Many of the important coal beds in western Europe, especially in the Ruhr Valley of Germany and in the Dutch coal-mining region of Limburg, Netherlands, are very friable, with the result that the run-of-mine product contains a large proportion of the sizes too fine to be treated successfully by any other method than froth flotation. Furthermore, the relatively high cost of producing coal from these beds has for many years made it economically feasible and desirable to treat the fines by froth flotation, especially in the coking-coal fields.

Western Germany has more froth-flotation plants and treats a larger tonnage by this process than any of the other countries on the continent. The largest single plant, however, is at the Dutch State Mines in Limburg Province, Netherlands. As a matter of fact, the Maurits plant of the State Mines is probably the largest froth-flotation plant in the world treating bituminous coal. It has the capacity to handle approximately 1,700 tons per 24-hour day.

The coal-preparation staff of Deutschen Kohlenbergbau Leitung reports that in the Ruhr area there are about 16 froth-flotation plants with a total capacity of 300 metric tons per hour. A visit to the principal builders of coal-preparation equipment showed several plants under construction that include froth-flotation equipment. Froth-flotation plants are also used to a considerable extent in the French mining industry, especially in the Saar basin.

In Great Britain there has been a very active interest in froth flotation during the last decade. A phenomenal upsurge in construction of plants took place in 1946. In that year, according to Grounds and Reed,4/ 18 froth-flotation plants were built, whereas the number of plants built from 1925 to 1945 averaged about 1 a year. In 1950, 43 plants were operating in England, Scotland, and Wales, according to Grounds and Needham.5/

---

4/ Grounds, A., and Reed, W., Progress in Coal-Preparation Practice: Institution of Mining Engineers, Trans., vol. 106, May 1947, p. 415.

5/ Grounds, A., and Needham, L. W., The Performance and Efficiency of British Coal-Preparation Plants: International Conf. on Coal Prep., Auspices, Cerchar, 35 Rue St. Dominique, Paris, France, June 1950, Contribution G4, p. 2.

The reasons for the increased emphasis have been referred to by Grounds, Needham, and Lewis in the following quotations (Grounds is chief coal-preparation engineer, British National Coal Board; Needham is divisional coal-preparation engineer for the Northeast Division of the British National Coal Board; Lewis is manager of Unifloc, Ltd., a company that for many years has specialized in the design and construction of froth-flotation plants):

> Generalizations are as dangerous in connection with coal preparation as with any other technical study, but it would seem that until a cleaning method of equal range is found, froth flotation should be extensively applied where fine coal must be cleaned, and that it should be used for whatever fractions will give a good friable, well-dewatered, and easily handled filter cake.6/
>
> Increasing attention is now being paid in England to flotation methods in view of the very high costs of coal and the increasing ash contents of most fine coals. The factor of increased ash is rendering unusable many slurries and fines which could previously be disposed of satisfactorily in boiler plants.7/
>
> Owing to the increase in the proportion of fine coal and the need for maximum recovery of useful coal, there has been a considerable increase of recent years in the application of froth flotation to the treatment of fine coals and slurries of minus 1/2 mm. to 0 in size, particularly where the froth-floated clean coal can be blended with the small coal for coking.
>
> Thus the general trend in Great Britain is to use a combination of three processes, dense-medium, Baum boxes, or trough washers, and froth flotation for cleaning of the whole of the run-of-mine coal.8/

Probably the most noticeable difference between flotation practice in Britain and the United States is that the British plants are usually operated on a closed-circuit basis, so that there is no desliming of the feed and no wasting of slurry water. The flotation tailings are usually flocculated with reagents and settled. The settlings are pumped either to lagoons or mine-refuse piles. The clear overflow water from the settling tank is returned to the washery circuit. Another noticeable difference between practice in this country and Britain is that coal-tar products, principally cresylic acid and creosote, are used rather universally as reagents both in Britain and on the continent instead of pine oil and the petroleum products used so extensively in this country.

In the present report, the froth flotation plants at the Dutch State Mines, Netherlands, and seven plants in England and Wales are described in considerable detail. Table 1 gives a list of the plants described and a brief summary of the salient data.

---

6/ Needham, L. W., The Cleaning of Fine Coal: Coll. Eng., vol. 226, May 1949, p. 174.

7/ Lewis, J. L., The Clarification of Coal Washery Water and Froth Flotation Treatment of Fine Coals in Great Britain: International Conf. on Coal Prep., Auspices, Cerchar, 35 Rue St. Dominique, Paris, France, June 1950, Contribution F7, p. 13.

8/ Work cited in footnote 5.

TABLE 1. - Summary of plants and of salient plant data

| Plant | Location | Type of flotation cells | Approximate top size of feed, mm. | Tons of feed per hr. | Ash analyses, percent | | |
|---|---|---|---|---|---|---|---|
| | | | | | Feed | Floated coal | Tailings |
| Emma ........... | Dutch State Mines | Mechanical (Kleinbentinck)... | 1/2 | 70 | 20.4 | 10.3 | 79.8 |
| Hendrik ........ | do. | do. | 1/2 | 45 | 18.3 | 5.7 | 65.5 |
| Maurits ........ | do. | do. | 1/2 | 70 | 18.6 | 6.5 | 73.4 |
| Dean and Chapter | Durham, England | Mechanical (subaeration type) | 1/2 | 20.7 | 23.4 | 6.5 | 70.0 |
| Mainsforth ..... | Durham, England | do. | 1/2 | 9.5 | 35.1 | 8.1 | 78.5 |
| Bentley ........ | Doncaster, England | Vacuum (Elmore) ............. | 1/2 | 6.6 | 25.2 | 14.4 | 42.8 |
| Grimethorpe .... | Barnsley, England | Mechanical (subaeration type) | 1/2 | 8.7 | 25.6 | 8.1 | 65.5 |
| Denby Hall ..... | Derby, England | do. | 3/4 | 20.0 | 30.0 | 13.0 | 68.0 |
| Windsor ........ | Caerphilly, Wales | do. | 1 | 9.5 | 18.6 | 6.0 | 69.0 |
| Middle Duffryn.. | Aberdare, Wales | do. | 1 | 30.0 | 20.0 | 4.0 | 62.0 |

# CURRENT FROTH FLOTATION PRACTICE ON THE CONTINENT

## Dutch State Mines

The largest froth-flotation plants handling coal in western Europe are at the Dutch State Mines in Limburg. There are three colliery preparation plants that have froth-flotation equipment. These are (1) the Maurits plant, which handles froth-flotation-size coal at the rate of 1,700 tons per day of 24 hours, (2) the Emma colliery plant, which handles approximately 1,400 tons a day, and (3) the Hendrik mine plant, which handles approximately 1,000 tons a day.

All these plants are equipped with Kleinbentinck flotation machines invented by the chief engineer of the Dutch State Mines.

The Kleinbentinck flotation machine is an exceptionally large mechanical-agitation-type cell shaped like an inverted truncated cone. Figure 1 shows its general appearance and arrangement. The tank is 3 meters in diameter and 0.8 meter deep, giving it a cubic capacity of 3,000 liters. The froth collects over the entire area of the cell and is discharged by a spiral sweep attached to the axial shaft.

At the State Mines, these cells are assembled in a series of five, as shown in figure 2. It is necessary to mount the cells on a stepped floor, so that the tailings from one cell will deliver by gravity to the next cell. A pipe connection is furnished for this purpose. All the State Mines plants operate on a simple series retreatment of the tailings through the five-cell flotation units, with no recleaning of the froth product.

At the Maurits plant, which is typical of the State Mines flotation plants, there are forty Kleinbentinck cells arranged in eight units of five cells, each operating in series as outlined above. This plant is capable of delivering 1,350 tons per day of 24 hours of dry flotation product. The feed to the plant is 1/2-mm. by 0 coal, which comes from spitzkasten that collects the wash water from the standard jig-washed coal-dewatering screens jacketed with 1/2-mm. wedge-wire cloth. A typical plant feed contains about 15 percent solids with an ash content of about 18 percent. The flotation plant delivers a concentrate of about 5-1/2 to 6-1/2 percent ash and a refuse of approximately 75 percent ash.

The froth carrying the cleaned coal from the flotation cells goes to a conical tank without any froth breaker, and from this storage tank the coal is drawn off to drum-type vacuum filters with stainless-steel wire cloth of 1/2-mm. mesh. These filters deliver a cake of about 25 percent moisture (the inherent vein moisture of the coal is 1 to 2 percent). At the Maurits plant, the filter cake then goes to rotary, kiln-type heat dryers and is then blended with the 10-mm. by 1/2-mm. jig-washed coal to produce the charge for the coke ovens. The dried filter cake from the heat dryers is delivered to the blend at about 11 percent moisture, and the 10-mm. by 1/2-mm. from the jig is dewatered in Reineveldt centrifuges to about 6 to 7 percent moisture.

At the State Mines flotation plants, the reagent commonly used is the waste liquor from the ammonia-recovery towers of the coke plant, but this is supplemented by small quantities of other reagents. A typical example of the use of reagents is the Maurits plant, where the average use of the ammonia-tower waste liquor amounts to 1.33 cubic meters of the lean liquor per dry ton of froth-flotation concentrate. This waste liquor contains an average 0.38 gram per liter of tar acids and 0.31 gram per liter neutral oil. Besides this waste liquor, the Maurits plant is currently

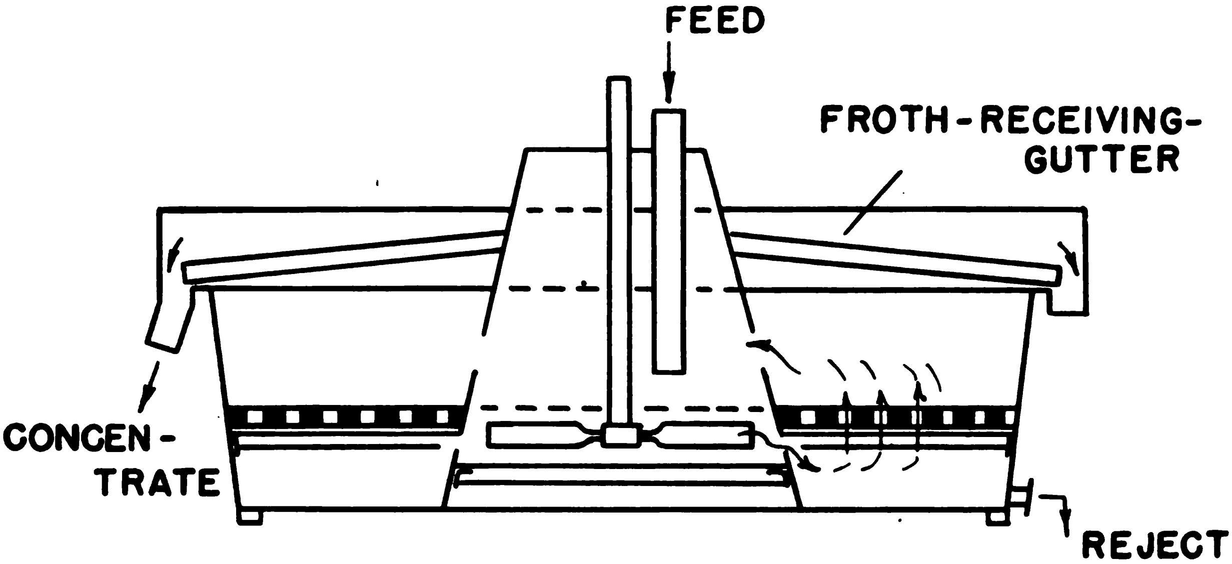


Figure 1. - Section through Kleinbentinck flotation cell.

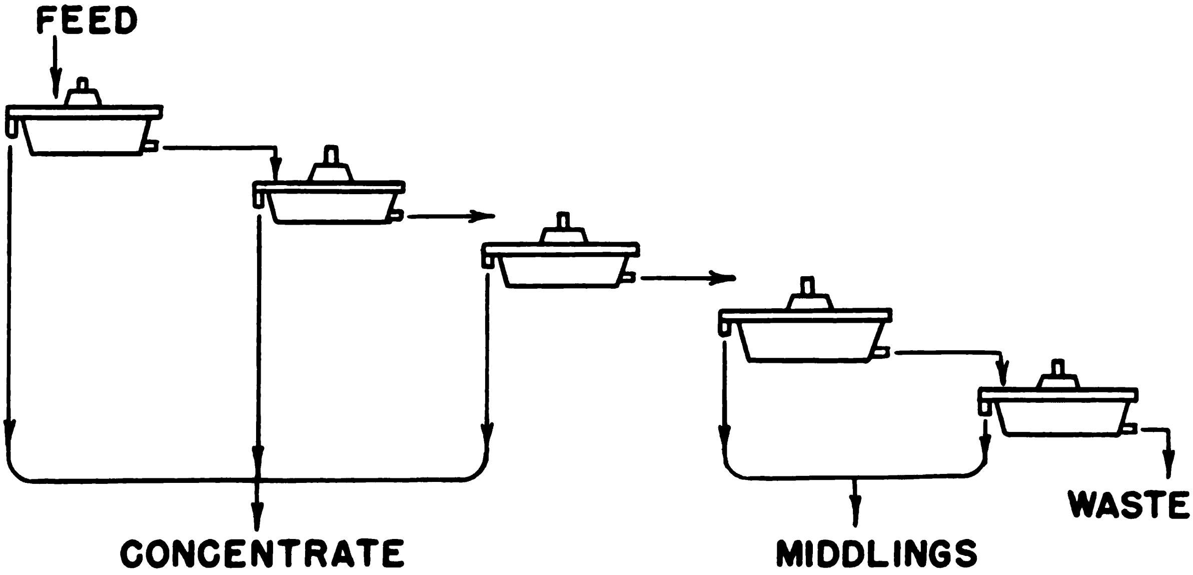


Figure 2. - Series arrangement of Kleinbentinck flotation cells.

using an average 0.21 kilogram per ton of middle oils from the coke plant. This crude middle-oil product contains 29 percent tar acids, and the rest is neutral and basic products.

It is the standard practice of these plants to use a rather large proportion of flotation oils derived from their own coke plants in order to obtain a froth product that filters very readily. At the time the plants were visited, some neutral gas oil from the coke plant was being used also to increase the filterability of the froth product. A summary of operating results at the State Mines is given in table 2.

TABLE 2. - Summary of operating data at the Dutch State Mines

| Mine | Emma | Hendrik | Maurits |
|---|---|---|---|
| Year built | 1922 | 1923 | 1928 |
| Daily capacity, metric tons 1/ | 8,000 | 3,200 | 10,500 |
| Recovery, clean coal, metric tons | 6,000 | 2,500 | 8,500 |
| Froth floated coal, metric tons | 2/ 1,100 | 600 | 1,350 |
| Number of groups of flotation machines | 5 | 3/ 5 | 8 |
| Number of machines per group | 5 | 6 | 5 |
| Total number of machines | 25 | 30 | 40 |
| Daily flotation feed, metric tons, dry | 1300-1400 | 750-1000 | 1600-1700 |
| Daily flotation tailings, metric tons, dry | 200 | 200 | 300 |
| Daily work time, hours | 19-20 | 19-20 | 24 |
| Ash content of feed, percent | 20.4 | 18.3 | 18.6 |
| Ash content of float coal, percent | 10.3 | 5.7 | 6.5 |
| Ash content of tailings, percent | 79.8 | 65.5 | 73.4 |
| Flotation reagent required, phenolic ammonia water, $M^3$ per hr. | 25 | 25 | 140 |
| Number of filters | 14 | 12(+2) | 18(+2) |
| Total filter surface, $M^2$ | 84 | 72(84) | 142 |
| Filtering rate, kg/$M^2$/hr. | 55-58 | 30-31.6 | 36.25 |
| Reagent required, kg. of tar oil per ton of dry floated coal | 2.7-3.3 | 3.4-11 | 3.5-8.5 |
| Average consumption, kg. of tar oil per ton of dry floated coal | 3 | 9.5 | 4.8 |

1/ Through-put for 1942/43 with 330 work days.
2/ Including middlings with 16.3 percent ash.
3/ In 1943 new cells were substituted for the old small cells.

## Water Clarification

The waste water from the froth-flotation plants and the jig washers at the State Mines collieries is clarified by flocculation in Dorr-type thickeners. The flocculating agent is a mixture of starch and ferrous sulfate, and the average reagent consumption ranges from 12 to 15 mg. of starch and 6 to 12 mg. of ferrous sulfate per liter of waste water fed to the tanks. The starch is specially treated, cold, and soluble. Sometimes it is boiled before use. At the Maurits colliery, the wash water from the washery is treated in a plant having two thickeners 20 meters in diameter. The flotation tailings go first to the No. 1 thickener, where the starch is added, and then to the No. 2 thickener, where more starch is added and finally the ferrous sulfate. Thickened sludge from the No. 1 thickener is filtered on vacuum filters and then wasted on the refuse dumps. The thickened sludge from the No. 2 thickener is too fine for handling on drum-type vacuum filters, and this sludge is delivered to settling ponds, from which the water is pumped back to the washery.

## Western Germany

In the Ruhr district of western Germany, many froth-flotation plants in general preparation plants were destroyed or immobilized during the war, but some of these have since been placed in operation. Generally, in Germany and France rectangular flotation-machine tanks equipped with mechanical agitators of the Minerals Separation type are used for froth-flotation of coal. In Western Germany, machines of this type are manufactured by the three large coal-preparation contracting companies, namely, Kloeckner-Humboldt-Deutz in Cologne, Schuchtermann-Kremer-Baum in Dortmund, and Westfalia-Dinnendahl-Groppel of Bochum. When the survey of plants was made, these manufacturers were active in developing preparation-plant projects, and several new plants with flotation equipment were under construction.

Unlike the State Mines practice, Western German practice in the handling of froth-flotation products usually includes a froth destroyer to condition the froth-flotation concentrate before it is delivered to the filters. The vacuum-tank type of froth destroyer, used almost exclusively in the German coal industry, has been described in a previous report.9/ This same paper also described the special froth-flotation treatment used in Germany during and before the war to prepare exceptionally clean coal to be used in the aluminum industry for carbon electrodes.

## New Developments in Froth Flotation Equipment and Techniques in Germany

### Flotation of Coarse-grain Coal

One of the difficult problems in the preparation of the finer sizes in Europe, as well as in America, is the treatment of the size intermediate between the flotation size and the smallest screened size adapted to efficient handling in gravity washing devices, such as feldspar jigs and launders.

One method that is being attempted to close the gap is to adapt the froth-flotation processes to handling coal grains up to 1-mm. or even 10 mesh in size. In this connection, the Westfalia-Dinnendahl-Groppel company has been conducting some interesting experiments under the direction of Dr. Quittkat, their froth-flotation specialist.

Dr. Quittkat has found that mechanical flotation cells of great depth will handle grains larger than the standard cells about 1 meter deep. His experiments were made with Minerals Separation-type cells of Wedag manufacture, conventional in every respect except that the cells that contain the pulp being treated are made 2 meters deep, and the agitator shaft is extended correspondingly. Dr. Quittkat found that with these cells he can successfully handle bituminous coal of the Ruhr type up to 1 millimeter in size. As a result of these experiments, he believes that the size of grain that can be floated is directly related to the depth of the pulp in the flotation cells. His explanation of this phenomenon is that the air bubbles entrained and released at the bottom of the cells by the motion of the high-speed agitators are very fine. As they ascend to the surface, traversing liquid of gradually decreasing static pressure, the bubbles expand and also are increased in size by the juncture of two or more bubbles. These larger bubbles will attach themselves to and lift larger particles of coal. Based on the results of their experiments, Dr. Karl Groppel, director of the company, expressed the opinion that they can now install froth-flotation plants to handle the raw coal of 1-mm. by 0 size.

---

9/ Fraser, Thomas, and Driessen, M. G., Coal-Preparation Practice in Western Germany: Bureau of Mines Inf. Circ. 7389, November 1946, p. 40.

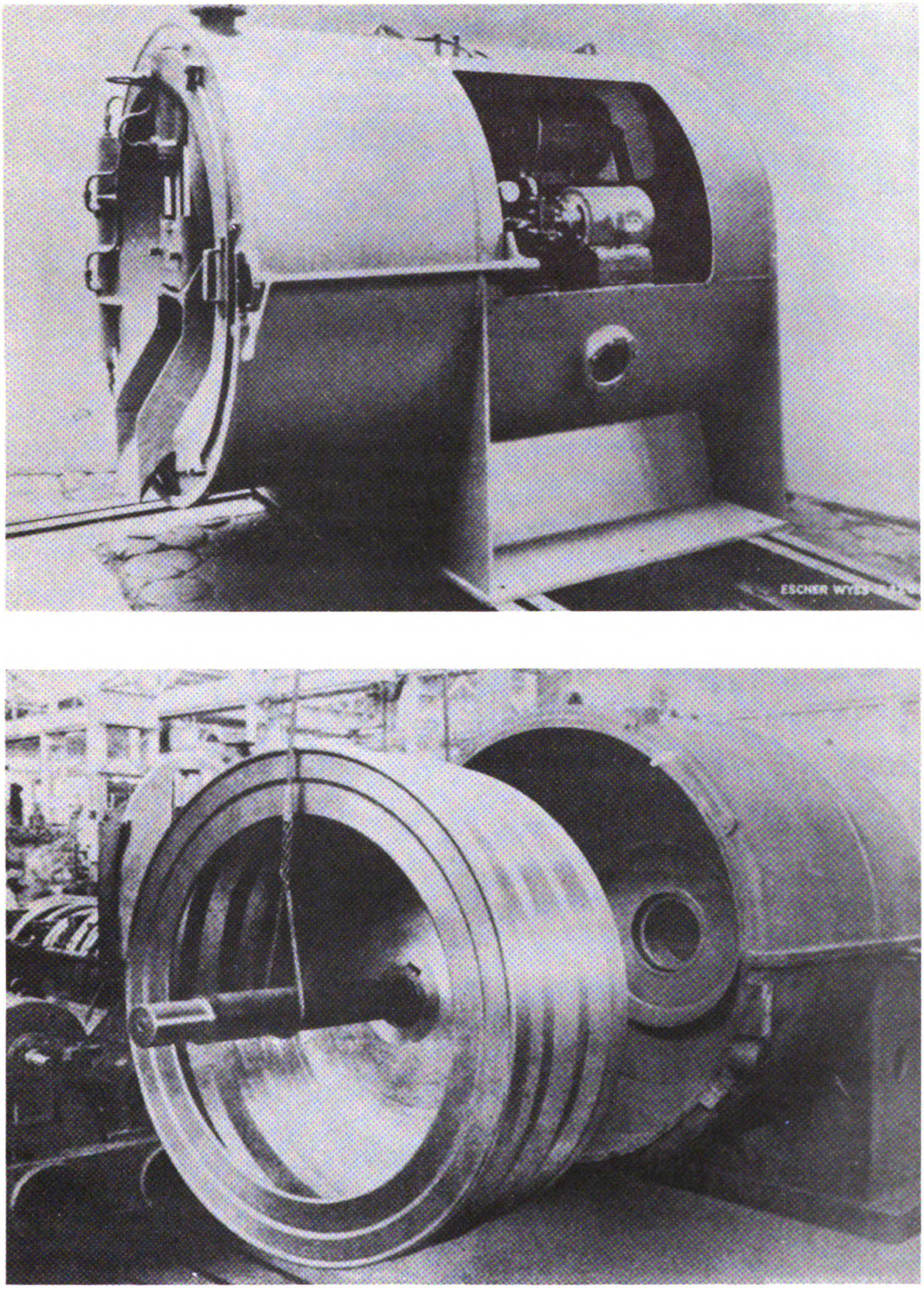


Figure 3. - Scraper-type Escher Wyss centrifuge.

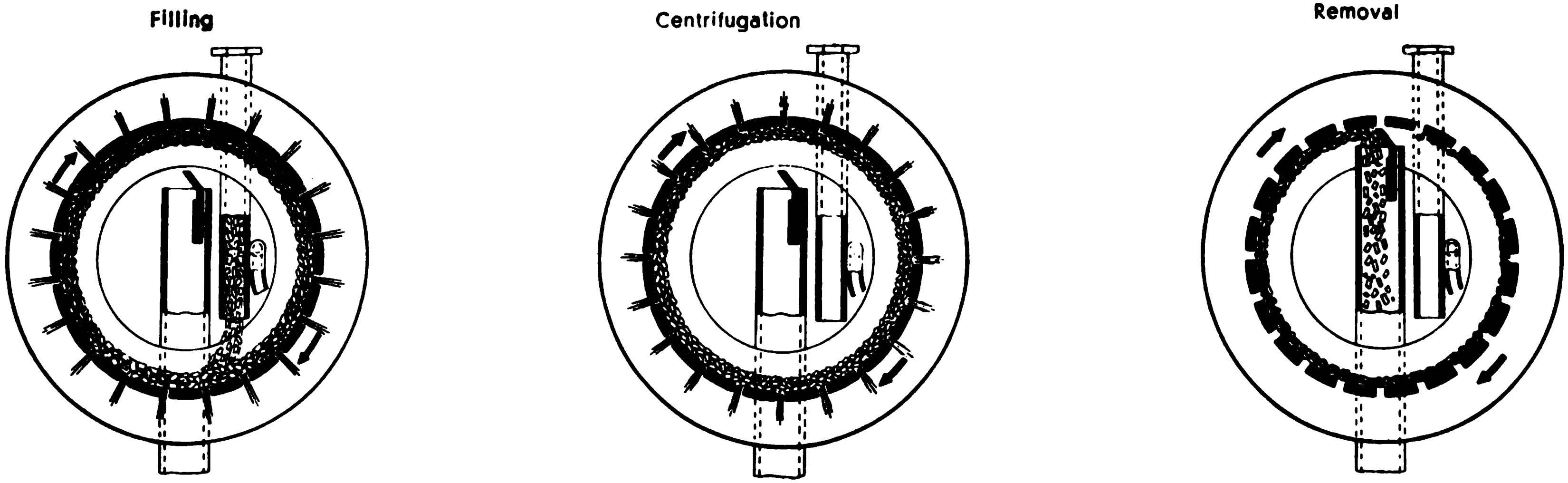


Figure 4. - Sectional views of the 3-cycle operation of the Escher Wyss centrifuge.

This same company (Westfalia-Dinnendahl-Groppel A. G.) has experimented also with the froth flotation of coal in dilute heavy-medium pulps, using very finely ground magnetite as the heavy-medium material. Dr. Quittkat reported that with the expedient of using a magnetite suspension of 1.2 specific gravity, they can float coal particles as large as 2 mm. However, they do not consider that this modification of the froth-flotation practice is of any great practical value.

## Dewatering of Fine Coal in Centrifuges; the Escher Wyss Batch-Type Centrifuge and the Centrifuge of Siebtechnik A. G.

At two preparation plants in the Aachen district of western Germany there are two commercial installations of the Escher Wyss centrifuge to handle very fine coal. One of these, at the Lauerweg colliery in Kohlscheid, is handling raw sludge, and the other, at the Adolph colliery in the same general area, is handling froth-flotation concentrates. Views of the Escher Wyss centrifuge are shown in figures 3 and 4.

These machines, manufactured in Zurich, Switzerland, are used principally in the chemical engineering industry, but, as mentioned, they are used at the Lauerweg and Adolph collieries for dewatering fine coal. Both intermittent scraper-type and continuous pusher-type Escher Wyss centrifuges are available, but those at Lauerweg and Adolph collieries are intermittent scraper-type. They have been in use for a considerable period, and performance data furnished by the operating company indicate that they are effective for reducing moisture in sludges of froth flotation size to about 15 percent with a loss of only 10 to 12 percent of the solids in the effluent. The operating engineer advised that this operation permits them to continue to circulate the washery water without bleeding of dirty water from the system. The following is a translation of their engineer's report of December 1949. As indicated in this report, filling, centrifuging, and scraping require about 10 minutes.

Plant: Slime centrifuge at mine Lauerweg.

Type: Bowl centrifuge design ter Meer, with 2 drums operating discontinuously.

Actual dimensions: Drum diameter, 2,500 mm.
Drum height, 750 mm.

Weight: Total, 35 tons without load.

Capacity of each drum: 1,750 L. Maximum equals around 1,350 kg. of finished coal.

Power needed: Filling, about 110 kw.
Drying, about 53 kw.
Scraping, about 150 kw.

Revolutions 500/min. Power required, 120 kw.

Operating cycle (fill, dry, and scrape) 2.00 + 7.10 + 0.50 = 9.60 min.

**Raw material:** **Fine slime from settling tank from flotation concentrate.**

| Grains, mm. | Feed | | Dried material | | Filtrate | |
|---|---|---|---|---|---|---|
| | Weight, percent | Ash, percent | Weight, percent | Ash, percent | Weight, percent | Ash, percent |
| + 3 ..................... | 0.4 | 3.4 | - | - | - | - |
| 3 - 1 ..................... | 5.6 | 5.4 | 2.9 | 10.2 | - | - |
| 1 - 0.5 ..................... | 18.2 | 8.0 | 12.7 | 8.5 | - | - |
| 0.5 - 0.3 ..................... | 21.2 | 10.5 | 22.9 | 10.6 | 0.5 | 32.5 |
| 0.3 - 0.1 ..................... | 32.2 | 15.0 | 36.5 | 11.0 | 10.5 | 19.5 |
| - 0.1 ..................... | 22.4 | 19.7 | 25.0 | 16.6 | 89.0 | 18.5 |
| Total .................. | 100.0 | 13.2 | 100.0 | 12.4 | 100.0 | 18.8 |
| Grain-size criterion ........ | d 0.36 | | 0.32 | | 0.05 | |
| According to Rosin-Ramler ... | n 1.16 | | 1.25 | | 1.3 | |
| Amount of moisture .......... | 39.9 $m^3$/hr. | | 16.1 ton/hr. | | 32.4 $m^3$/hr. | |
| Solid material content g/l .. | 405 | | - | | 61.5 | |
| Amount of dried ton/hr. ..... | 15.58 | | 13.6 | | 1.98 | |
| Water content, percent ...... | - | | 15.5 | | - | |
| Weight yield, percent ....... | 100 | | 87.3 | | 12.7 | |

Remarks: 18 ton/hr. dry solids in feed.
70 kw. per hour power consumption.
70,000 marks capital cost in 1942.
140,000 marks would be cost now.
0.30 marks operating cost per ton of dry coal.

Wear: The filter cloth on the side filter lasts about 3-1/2 months, corresponding to around 10,500 tons of raw material (dry weight).
The casing filter cloth lasts considerably longer.

Siebtechnik A. G. has developed a small, high-speed, vertical, continuous centrifuge particularly adapted to handle sludges of froth-flotation size. It is more like the conventional centrifuge dryer commonly used in the United States. One of these machines is being operated experimentally in the laboratory of Siebtechnik at Muelheim, Ruhr, but is not yet in commercial use. The inventor, Dr. Lange, of the Siebtechnik organization, proposes to make them in several sizes up to 900-mm. in diameter of basket. From pilot-scale tests, he believes that this machine will reduce the moisture of 1/2-mm. by 0 slurries to as low as 9 percent of surface moisture but will probably lose 20 to 30 percent of the solids in the effluent.

Tentative flow diagrams discussed with the company indicate that they do not hope to close the washery circuit completely with this device but plan to discharge the effluent to storage tanks and finally to recover the effluent solids by use of vacuum filters. To the authors, it is a little difficult, however, to see how the use of both a centrifuge and vacuum filters could be advantageous when vacuum filters alone can do the entire job.

## FROTH FLOTATION PRACTICE IN GREAT BRITAIN

There are probably more froth-flotation plants in Great Britain treating coal than in any of the countries on the continent, but none of them treat particularly

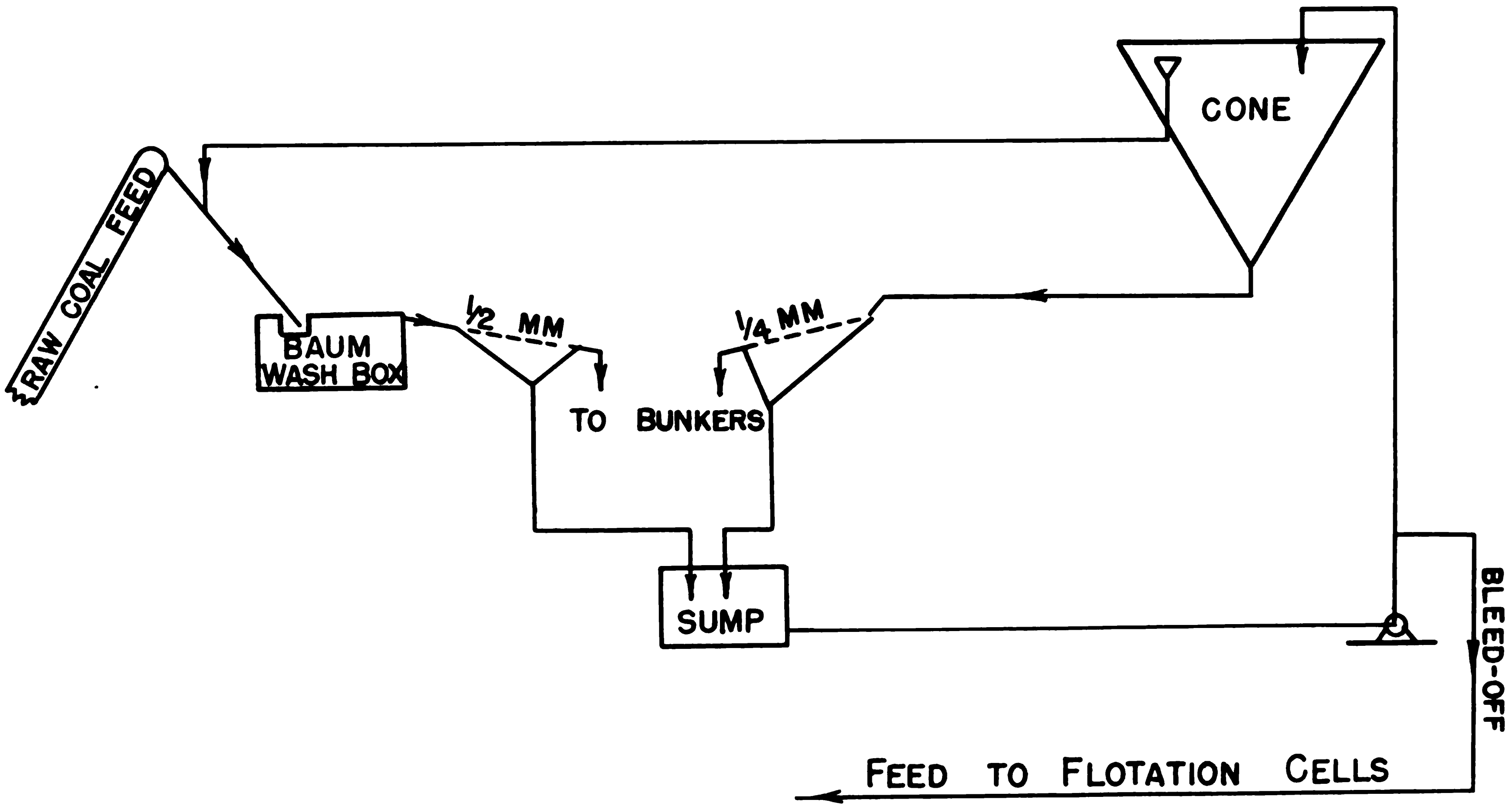


Figure 5. - Sketch showing origin of flotation cell feed at Dean and Chapter and Mainsforth plants.

large tonnages. According to Grounds and Needham, 43 plants were operating in 1950 with an average capacity of a little over 11 tons[10] per hour per plant.[11]

It is doubtful that any of the plants are treating more than 30 tons per hour. Plans were well-advanced, however, in the summer of 1950 for construction of at least one plant that will have several times the capacity of the largest plants now in operation.

The enormous divergence in floatability between some of the coals treated by froth flotation in Britain is rather surprising, considering that they are all of bituminous rank. The medium "caking coals" of the East Midlands division with about 35 percent volatile matter, for instance, are extremely difficult to float, require large quantities of reagents, long periods of conditioning, and a low feed volume per cubic foot of cell volume. On the other hand, in South Wales the entire range, from the semianthracite coals of about 12 percent volatile to the strongly coking coals of about 25 percent volatile, is so responsive to flotation that only a small quantity of reagents and a short period of conditioning and cell retention are needed for high capacities per cubic foot of cell volume.

During visits in Britain, comprehensive data were obtained on seven plants that were selected as being representative of practice in England and Wales. Scotland was not included in the itinerary of plant visits, as only 4 of the 43 present froth-flotation plants are situated there. Furthermore, the Scottish plants, according to the National Coal Board authorities, do not differ materially from those in England and Wales. Data were obtained at the following plants: Dean and Chapter, Mainsforth, Bentley, Grimethorpe, Denby Hall, Windsor, and Middle Duffryn. The distribution of these plants, according to divisions designated by the National Coal Board, is as follows: Dean and Chapter and Mainsforth are in the Northern Division, Bentley and Grimethorpe in the North-Eastern Division, Denby Hall in East Midlands Division, and Windsor and Middle Duffryn in the South-Western Division, which includes the southern part of Wales. Of these plants, Denby Hall, on one hand, and Windsor and Middle Duffryn, on the other, represent the two extremes as far as floatability of coal is concerned, the coal being particularly difficult to float at Denby Hall and extremely easy at Windsor and Middle Duffryn.

## Operating Data from Individual Plants

The Dean and Chapter and Mainsforth mines are about 9 miles south of Durham and only about a mile apart. Both produce metallurgical coking coals with volatile analyses in the 20 to 30 percent range. In both plants, the feed to the froth-flotation cells is an underflow product from wedge wire dewatering screens. Figure 5 shows the part of the flow sheets from which the flotation feed is derived. The 4-inch to 0 washed coal from Baum-type jigs is first dewatered on 1/2-mm. wedge wire. The underflow goes to a sump, from which it is pumped into a settling cone. The overflow from the cone is recirculated to the jigs, and the underflow is dewatered on 1/4-mm. wedge wire. The underflow from the 1/4-mm. wedge wire also goes into the sump. The flotation feed is obtained as a bleed-off from the riser to the settling cone. The bleed-off product goes directly to the feed conditioners in both plants without any desliming or thickening. At Dean and Chapter the solids in the feed average about 7.2 percent, and the conditioning time is about 4.8 minutes. Tonnage treated is 20.7 tons per hour, but the maximum capacity of the flotation cells is considered to be 27 tons per hour. There are four 5-cell units of the Denver subaeration type, 43 by 43 inches in size. The 5 cells in each unit are in series, and only two products - floated coal and tailings - are made. No fresh water is added to the feed. Flotation reagents are 2.1 pounds of creosote-cresylic acid mixture (about 2 to 1 proportion) per ton of floated product, dry basis.

---

[10] The "tons" used in the following pages in connection with British flotation plants means the British ton of 2,240 lb.

[11] Work cited in footnote 5.

At Mainsforth, the feed solids average about 9.1 percent, and conditioning time is about 6.9 minutes. A little over 9 tons of feed is treated per hour, but the maximum capacity of the cells is about 12 tons per hour. There are two units of cells with 5 Denver 43 by 43 inch subaeration-type cells in series in each unit. The only products made are floated coal and tailings. The same kind of reagent mixture is used as at Dean and Chapter. The quantity of reagents is about 2-1/4 pounds per ton of floated coal, dry basis. No fresh water is used in the flotation feed.

The system of handling the floated coal and tailings is the same in the Dean and Chapter and Mainsforth plants. The floated product goes directly to drum-type, rotary, vacuum filters for dewatering, whereas the tailings are flocculated and settled in thickeners, the settled product being pumped to lagoons or ponds. The clear-water overflow from the thickener is returned to the washery circuit.

Table 3 shows the average ash and screen analyses of the flotation feed, floated coal, and tailings based on operating records.

TABLE 3. - Screen and ash analyses (dry basis) of flotation products at Dean and Chapter and Mainsforth

| | | Dean and Chapter | | Mainsforth | |
|---|---|---|---|---|---|
| | Screen size, B S S1/ | Weight, percent | Ash, percent | Weight, percent | Ash, percent |
| Feed | (Plus 40 mesh ............... | 20.9 | 9.1 | 11.0 | 13.1 |
| | (- 40 + 60 mesh ............. | 11.8 | 17.9 | 8.5 | 22.4 |
| | (- 60 + 100 mesh ............ | 10.0 | 22.9 | 10.0 | 28.3 |
| | (-100 + 200 mesh ............ | 10.1 | 21.8 | 10.8 | 29.6 |
| | (Minus 200 mesh ............ | 47.2 | 30.9 | 60.0 | 43.0 |
| | (Composite .................. | 100.0 | 23.4 | 100.0 | 35.1 |
| Float coal | (Plus 20 mesh ............... | 12.0 | 2.2 | 5.0 | 2.3 |
| | (- 20 + 40 mesh ............ | 12.7 | 3.8 | 9.3 | 4.1 |
| | (- 40 + 60 mesh ............ | 12.0 | 6.1 | 10.7 | 5.6 |
| | (- 60 + 100 mesh ............ | 9.3 | 7.0 | 9.3 | 7.3 |
| | (-100 + 200 mesh ............ | 13.3 | 6.6 | 11.4 | 7.5 |
| | (Minus 200 mesh ............ | 40.7 | 8.7 | 54.3 | 10.2 |
| | (Composite2/ ................ | 100.0 | 6.5 | 100.0 | 8.1 |
| Tailings | (Plus 40 mesh ............... | 8.4 | 39.4 | 4.1 | 41.1 |
| | (- 40 + 60 mesh ............ | 8.1 | 62.1 | 8.6 | 67.4 |
| | (- 60 + 100 mesh ............ | 8.2 | 68.2 | 8.3 | 74.8 |
| | (-100 + 200 mesh ............ | 9.8 | 69.7 | 11.1 | 77.2 |
| | (Minus 200 mesh ............ | 65.5 | 72.1 | 67.9 | 82.7 |
| | (Composite .................. | 100.0 | 70.0 | 100.0 | 78.5 |

1/ British Standards Series.

2/ Moisture in filter cake is 27.6 percent at Dean and Chapter and 30.3 percent at Mainsforth.

The Grimethorpe mine is about 5 miles northeast of Barnsley. It produces a coking coal of about 35 percent volatile-matter content. The froth-flotation feed in the Grimethorpe plant is an underflow, product from 1/2-mm. wedge-wire slurry dewatering screens. The 3-1/2 inch to 0 run-of-mine coal is washed in Simon Carves Baum-type jigs, and the washed coal is dewatered on 3/4-mm. wedge-wire screens. The underflow from this dewatering goes to a settling cone. The underflow from the settling cone is dewatered on 1/2-mm. wedge wire, the screen underflow making up the flotation feed. It goes directly to the conditioner, where enough clear water is added to give a product of about 15 percent solids. Conditioning time is about 10 minutes. About 8.7 tons per hour are treated in the flotation unit, which consists of nine 35 by 35 inch Knapp and Bates cells similar to the Denver subaeration type, all nine cells being connected in series. Only two products are made - floated coal and tailings. The reagent mixture consists of about one-third cresylic acid and two-thirds creosote, and consumption is about 1-1/4 pounds per ton of dry solids treated. The floated coal goes directly to a rotary-drum vacuum filter for dewatering. The tailings are pumped to the refuse pile without flocculating or thickening. The ash and screen analyses of the feed, floated coal, and tailings are as shown in table 4.

TABLE 4. - Screen and ash analyses (dry basis) of flotation products at Grimethorpe

| | Screen size, B S S | Weight, percent | Ash, percent |
|---|---|---|---|
| Feed | Plus 16 mesh | 2.4 | 3.0 |
| | - 16 + 30 mesh | 18.5 | 8.7 |
| | - 30 + 60 mesh | 23.1 | 13.3 |
| | - 60 + 120 mesh | 20.0 | 35.5 |
| | - 120 + 240 mesh | 13.1 | 40.4 |
| | Minus 240 mesh | 22.9 | 37.1 |
| | Composite | 100.0 | 25.6 |
| Float coal | Plus 16 mesh | 2.6 | 8.3 |
| | - 16 + 30 mesh | 15.5 | 3.3 |
| | - 30 + 60 mesh | 26.0 | 4.4 |
| | - 60 + 120 mesh | 18.3 | 8.9 |
| | - 120 + 240 mesh | 11.2 | 11.2 |
| | Minus 240 mesh | 26.4 | 12.7 |
| | Composite[1] | 100.0 | 8.1 |
| Tailings | Plus 16 mesh | 1.5 | 9.2 |
| | - 16 + 30 mesh | 11.9 | 11.9 |
| | - 30 + 60 mesh | 9.8 | 38.6 |
| | - 60 + 120 mesh | 23.2 | 76.8 |
| | - 120 + 240 mesh | 12.6 | 82.2 |
| | Minus 240 mesh | 41.0 | 77.8 |
| | Composite | 100.0 | 65.5 |

[1] Percent moisture in filter cake, 26.8.

The Bentley mine is about 1 mile north of Doncaster. Coal produced at this mine is weakly coking and has a volatile-matter content of about 37 percent. The froth-flotation feed in the Bentley plant is obtained by the same system as at Grimethorpe, except that a certain amount of "fines" is removed from the run-of-mine coal by pneumatic dedusting and added to the flotation feed. Owing to the wetness of the run-of-mine coal, however, the dedusting process is very inefficient.

Another slight variation is that the flotation feed passes through a 1-mm. scalping screen for removal of the coarse tramp material. On this screen, enough water is used to give a flotation feed of about 29.7 percent solids. The Bentley plant is one of three in Britain using the Elmore vacuum froth-flotation process. It is an old plant, built in 1934, and does not have the refinements incorporated in the plants built more recently. The Bentley vacuum cell is 7 feet in maximum diameter and 13 feet high. The feed is conditioned in a paddle-type mixer before entering the cell. Conditioning time is about 5 minutes, and feed rate is about 6.6 tons per hour. Kerosine is used as reagent at the rate of about 4 pounds per ton of feed. The floated coal goes directly to a drum vacuum filter for dewatering, whereas the tailings are flocculated and settled in a tank. The settled product is removed by a bucket elevator to cars for drainage and then dumped on the shale pile. Owing to the high percentage of solids in the feed and a rather low recovery by weight of float product, the tailings as discharged from the Elmore cell have a solids content of about 32 percent. Table 5 gives the ash and screen analyses of the feed, floated coal, and tailings at Bentley.

TABLE 5. - Screen and ash analyses (dry basis) of flotation products at Bentley

| | Screen size, B S S | Weight, percent | Ash, percent |
|---|---|---|---|
| Feed | (Plus 16 mesh | 0.7 | 3.4 |
| | (- 16 + 30 mesh | 9.0 | 4.0 |
| | (- 30 + 60 mesh | 25.0 | 8.6 |
| | (- 60 + 120 mesh | 22.4 | 28.5 |
| | (- 120 + 240 mesh | 30.5 | 37.3 |
| | (Minus 240 mesh | 12.4 | 37.9 |
| | (Composite | 100.0 | 25.2 |
| Float coal | (Plus 16 mesh | 0.6 | 8.0 |
| | (- 16 + 30 mesh | 11.5 | 4.9 |
| | (- 30 + 60 mesh | 27.5 | 6.7 |
| | (- 60 + 120 mesh | 19.6 | 13.8 |
| | (- 120 + 240 mesh | 21.7 | 20.5 |
| | (Minus 240 mesh | 19.1 | 25.2 |
| | (Composite[1] | 100.0 | 14.4 |
| Tailings | (Plus 16 mesh | 2.4 | 5.5 |
| | (- 16 + 30 mesh | 13.3 | 12.4 |
| | (- 30 + 60 mesh | 20.7 | 26.3 |
| | (- 60 + 120 mesh | 27.7 | 54.9 |
| | (- 120 + 240 mesh | 25.0 | 58.2 |
| | (Minus 240 mesh | 10.9 | 53.2 |
| | (Composite | 100.0 | 42.8 |

[1] Percent moisture in filter cake, 32.7.

The Denby Hall mine is about 8 miles north of Derby. The type of coal produced at this mine is medium caking coal of about 35 percent volatile matter. In this plant, the minus 1/2 inch to 0 is screened out of the raw coal and washed in Hoyois troughs. The washed coal from the troughs is dewatered on screens from which the underflow goes to a settling cone. The underflow from the cone is dewatered on 3/4-mm. slurry screens, and the underflow constitutes the feed to the froth flotation plant. The cone overflow is returned to the circuit. The flotation feed is conditioned for about 14 minutes, and fresh water is added so that the percentage of solids

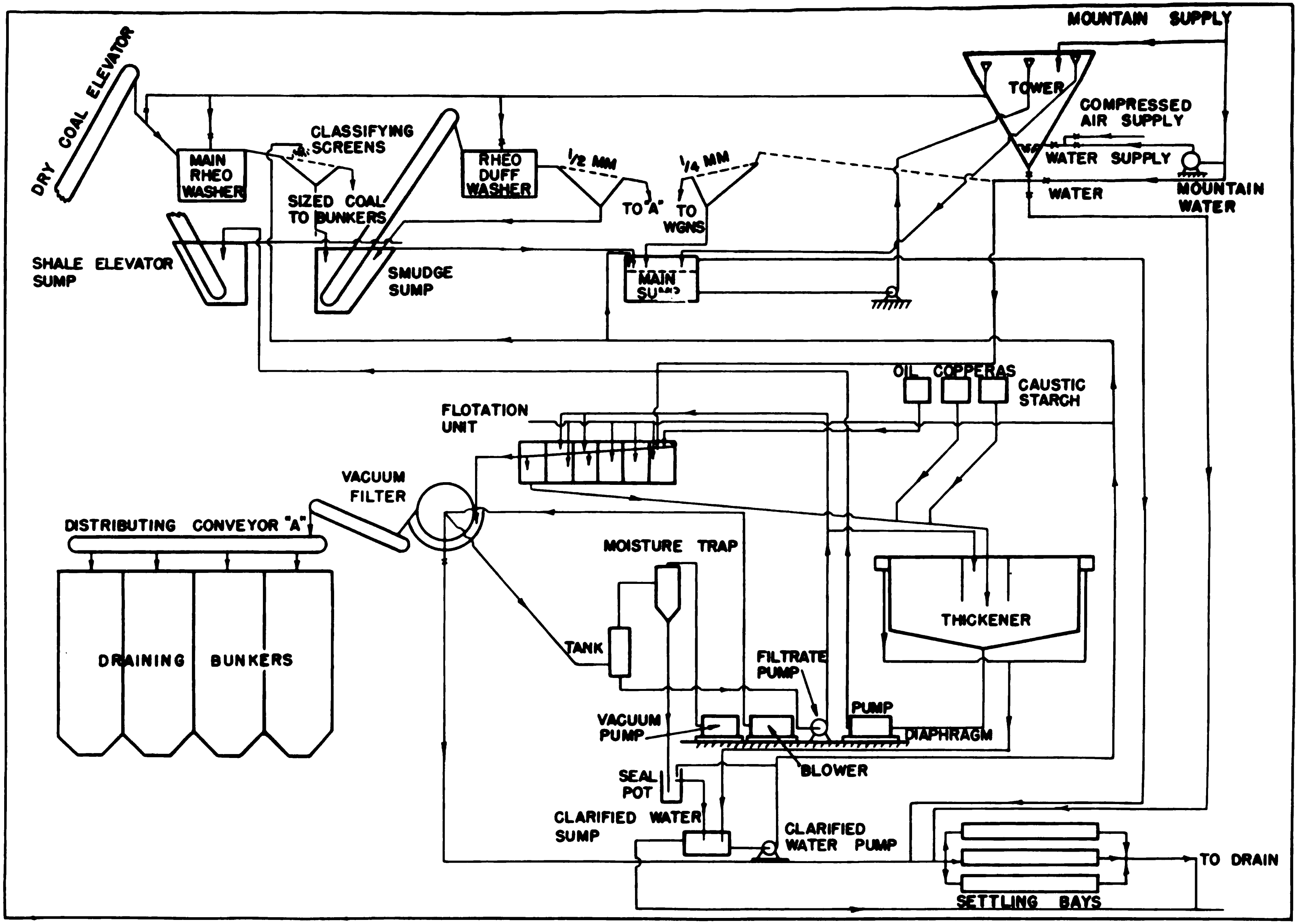


Figure 6. - Flow-sheet at Windsor plant.

is about 12.5 percent. About 20 tons per hour, dry weight, are treated. In this plant there are two units of primary cells, 6 cells to a unit, and two units of recleaners, with 5 cells to a unit. The cells are 43 by 43 inch Denver subaeration type. The float product from the two primary units is retreated in the two recleaner units, with no retreatment of the tailings. The usual cresylic acid-creosote combination is used as reagent in the amount of about 3-1/2 pounds per ton of dry feed. The float product is flumed directly to rotary-drum vacuum filters for dewatering. The tailings are flocculated, settled, and pumped to a lagoon. The overflow water from the settling tank is returned to the circuit.

The ash analysis of the flotation feed is approximately 30 percent, float coal 12 to 14 percent, and tailings to 70 percent. Screen analyses of the products are given in table 6.

TABLE 6. - Screen analyses of flotation products at Denby Hall

| Screen size, B S S | Weight, percent | | |
|---|---|---|---|
| | Feed | Float coal | Tailings |
| Plus 1/16 inch | 0.2 | 1.8 | 0.9 |
| - 1/16 in. + 25 mesh | 11.0 | 14.9 | 18.9 |
| - 25 + 60 mesh | 41.5 | 29.5 | 43.5 |
| - 60 + 100 mesh | 16.7 | 18.9 | 15.0 |
| -100 + 200 mesh | 13.7 | 13.5 | 10.9 |
| Minus 200 mesh | 16.9 | 21.4 | 10.8 |

The Windsor mine, about 3 miles from Caerphilly in southern Wales, produces a good metallurgical coking coal in the 20 to 30 percent volatile-matter range. The source of the froth flotation feed in the Windsor plant is shown in figure 6, which is a copy of a drawing prepared by the engineering staff at the plant. The 3-inch to 0 run-of-mine coal is washed in Rheolaveur launders. The washed coal from the main Rheo washer goes to classifying screens, the underflow going to a sludge sump that also serves as an elevator boot. The main part of the coal going into this sump is removed by an elevator and fed to a Rheo duff washer. The cleaned duff size from this washer is dewatered on 1/2-mm. screens, the underflow from which returns to the sludge sump. The overflow from the sump carrying the "fines" in suspension goes to a main sump, from whence it is pumped into a settling tower or cone. The overflow from this cone returns to the washery circuit, whereas the underflow is the source of the flotation feed. There is also an equalizing line from the cone back to the main sump to keep the overflow level in the cone constant. There is considerable flexibility for handling the cone underflow. The entire underflow may be sent directly to the flotation cells or, in case of an overload, a part of it can be sent to the settling bays to be disposed of later. Part of it can also be sent to a 1/4-mm. dewatering screen for removal of 1/4-mm. oversize ahead of the flotation cells. It will also be noticed in figure 6 that the overflow from the vacuum filter tank can be run to the settling bays in case of an overload on the filter.

The coal at the Windsor plant is extremely easy to treat by froth flotation, and no conditioner is used. Some fresh water is added to bring the solids in the feed down to about 23 percent. About 9.5 tons per hour of feed are treated in a 6-cell unit of Minerals Separation cells. The agitation chambers in these cells are of 32 by 32 inches, but cell volume based on these dimensions would be misleading without taking into account the fact that a Minerals Separation cell is equipped with a spitzkasten or frothing chamber about twice the volume of the agitation chamber. The six cells are operated in series, and only two products - floated coal and tailings - are made. There is no retreatment of the products. The reagent used is a 2 to 1 mixture of creosote and cresylic acid. Of this mixture, 0.6 pound is used per ton of dry solids treated. The float product goes directly to the rotary-drum vacuum filter for dewatering.

An interesting feature of the filter drum in the Windsor plant is that it has been converted to overhead feed with highly satisfactory results. The tank for feeding the drum is built around an upper quadrant of the drum instead of under the lower half. This system has increased the capacity of the filter besides giving a product of lower moisture content than was formerly obtained with the underfeed system. The plant engineers attribute the success of the overhead feed to the fact that the floated coal contains an unusually high proportion of the coarser sizes. They do not feel that the overhead system would be feasible with a float product of normal size consist.

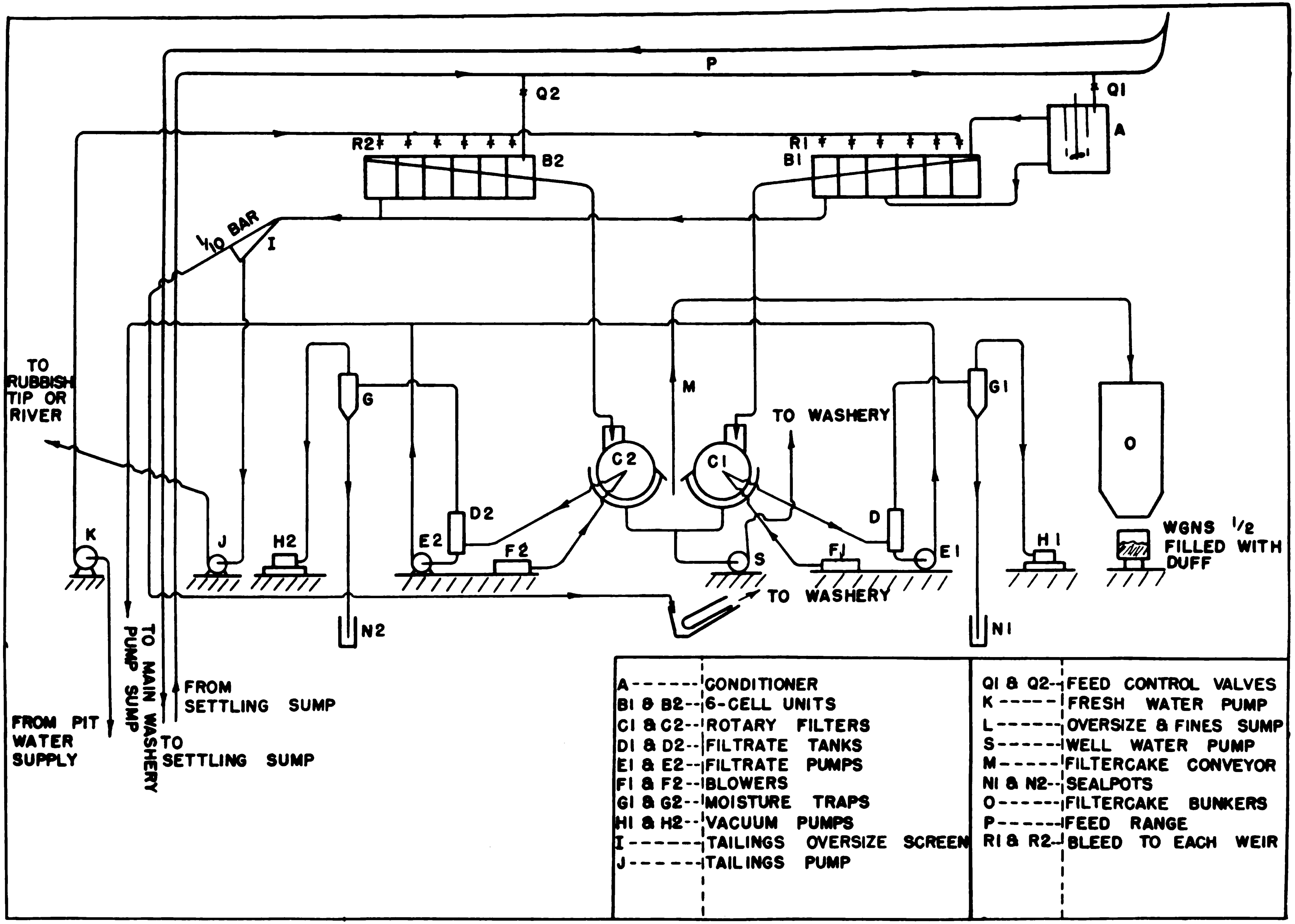
As indicated in figure 6, the flotation tailings are flocculated and settled in a thickener. The thickened product is disposed of to the shale elevator sump by means of a diaphragm pump.

The ash analyses of the flotation products are: feed, 18.6 percent; floated coal, 6.0 percent; tailings, 69.0 percent. Screen analyses of the products are shown in table 7.

TABLE 7. - Screen analyses of flotation products at Windsor

| Screen size, B S S | Weight, percent | | |
|---|---|---|---|
| | Feed | Float coal | Tailings |
| Plus 30 mesh .................................... | 27.0 | 28.9 | 6.5 |
| - 30 + 60 mesh ................................ | 30.9 | 31.2 | 14.3 |
| - 60 + 90 mesh ................................ | 16.9 | 15.9 | 19.0 |
| Minus 90 mesh ................................. | 25.2 | 24.0 | 60.2 |

The Middle Duffryn mine, in Aberdare, southern Wales, produces what is known as a "dry" steam coal, noncaking in the 10 to 14 percent volatile matter range. Figure 7, a drawing from the plant's engineering office, shows the flow sheet for the froth-flotation plant. A Baum-type jig is used for washing the run-of-mine coal after a very inefficient dedusting by aspiration. The washed coal from the jig is dewatered on 1/2-mm. screens, the underflow going to a settling sump. The overflow from this sump is returned to the washer circuit. The underflow is pumped through a pipe that connects at the upper end with the pipe carrying the dewatering screen underflow to the sump. The flotation feed is drawn through the control valves from the pipe carrying the settling sump underflow. Before entering the flotation cells, the feed is given a 7.7 minutes conditioning with a 2-to-1 mixture of creosote and cresylic acid. The amount of this mixture used for conditioning and flotation is 0.7 pound per ton of dry feed. The feed contains about 25 percent solids, but a certain amount of fresh water is added to the individual cells. There are two 6-cell Minerals Separation units with 32 by 32 inch agitation chambers. The spitzkasten, or frothing chamber, of each cell has about twice the volume of the agitation chamber. The six cells in each unit operate in series, and only a floated product and tailings are made. The two units treat a total of about 30 tons per hour. The floated coal is dewatered on two vacuum filter drums, the filtrate returning to the main washery circuit. As in the Windsor plant, the filter drums have been converted to overhead feed. The flotation tailings are pumped directly to the spoils heap without flocculating or thickening. The tailings, however, pass through a 1/10 inch bar



| | |
|---|---|
| A | CONDITIONER |
| B1 & B2 | 6-CELL UNITS |
| C1 & C2 | ROTARY FILTERS |
| D1 & D2 | FILTRATE TANKS |
| E1 & E2 | FILTRATE PUMPS |
| F1 & F2 | BLOWERS |
| G1 & G2 | MOISTURE TRAPS |
| H1 & H2 | VACUUM PUMPS |
| I | TAILINGS OVERSIZE SCREEN |
| J | TAILINGS PUMP |
| Q1 & Q2 | FEED CONTROL VALVES |
| K | FRESH WATER PUMP |
| L | OVERSIZE & FINES SUMP |
| S | WELL WATER PUMP |
| M | FILTERCAKE CONVEYOR |
| N1 & N2 | SEALPOTS |
| O | FILTERCAKE BUNKERS |
| P | FEED RANGE |
| R1 & R2 | BLEED TO EACH WEIR |

Figure 7. - Froth flotation flow-sheet at the Middle Duffryn plant.

screen first to remove coarse coal particles that were not recovered by flotation. This oversize is returned to the washer circuit.

The ash analyses of the products are approximately as follows: feed, 20 percent; floated coal, 4.0 percent; tailings, 62.0 percent. The size distribution in the various products is shown in table 8.

TABLE 8. - Screen analyses of flotation products at Middle Duffryn

| Screen size, B S S | Weight, percent | | |
|---|---|---|---|
| | Feed | Float coal | Tailings |
| Plus 30 mesh | 43.5 | 44.5 | 46.7 |
| - 30 + 60 mesh | 32.0 | 33.7 | 26.4 |
| - 60 + 72 mesh | 7.0 | 5.2 | 11.2 |
| - 72 + 240 mesh | 15.0 | 11.0 | 10.2 |
| Minus 240 mesh | 2.5 | 5.6 | 5.5 |

## Costs and Power Requirements

The operating costs in the seven plants show extremely wide variations. The extremity of these variations may be partly attributable to differences in methods of defining costs, and such differences can make individual figures misleading. In order not to overemphasize figures on an individual basis, cost data representing only the maximums, minimums, and averages are given in table 9. The figures in this table include all the operating costs of conditioning, flotation, float-coal filtering, and tailings handling and disposal. The highest total cost per ton of feed was 48.1 d at Denby Hall, where the coal is extremely difficult to treat by froth flotation. The lowest total cost per ton of feed was 13.5 d at the Middle Duffryn plant, where the coal is very amenable to froth flotation. A further consideration at Middle Duffryn that helps to keep cost figures at a minimum is the fact that the flotation tailings are pumped directly to the spoils heap without flocculation or thickening. At Denby Hall, the tailings thickening, settling, and disposal represents an appreciable item of cost.

TABLE 9. - Flotation-plant operating costs per ton of feed; maximums, minimums, and averages for the seven plants

| Item | Maximum | Minimum | Average |
|---|---|---|---|
| Labor | 1 s 10.4 d | 4.9 d | 12.1 d |
| Power | 8.9 d | 3.5 d | 5.7 d |
| Reagents | [1] 1 s 10.0 d | [2] 1.6 d | 6.5 d |
| Maintenance (labor and supplies) | 10.0 d | 0.4 d | 3.4 d |

[1] Includes flocculating reagents.
[2] No flocculating reagents included.
Note: In 1950, a shilling was equivalent to about 14.1 cents. Pence are 1/12 of a shilling.

Some of the cost figures used in compiling table 9 are on the basis of the pound sterling prior to devaluation in 1949. It seemed the concensus of opinion among operators in the summer of 1950, however, that costs had not increased materially - probably not more than 5 percent - in terms of English currency as a result of the devaluation.

Only three of the seven plants had records showing power requirements itemized as pumping, thickening, conditioning, flotation, and product dewatering, and they showed considerable discrepancy as to what power items are chargeable to the froth-flotation plant rather than to handling of the circulating water for the preparation plant as a whole. The total installed horsepower for operation of the flotation plants ranged from 5.7 hp. per ton hour of feed in the Middle Duffryn plant to 22 hp. per ton hour of feed in the Denby Hall plant. The other five plants averaged 13.9 hp. per ton hour of feed. These figures represent the totals for pumping, tailings disposal, conditioning, flotation, and float-coal filtering. It should be pointed out that in most cases the actual power used is considerably less than the "installed" horsepower. Available information indicated that actual kilowatt load averaged about 70 percent of what it would be on the basis of the installed horsepower. In one case a plant was running at only 76 percent of capacity and at a kilowatt load less than 50 percent of that indicated by the total installed horsepower.

## Noticeable Differences Between Froth Flotation Practice in Great Britain and the United States

The most conspicuous differences between British and American flotation practice are in the size of the plants, the more general use of dewatering screens and closed circuits in Britain, and the almost universal use of the commonly available coal tar products, particularly cresylic acid and creosote, as flotation reagents instead of pine oil and the petroleum products used so extensively in the United States. In all the plants visited, dewatering screens played some part in the removal of the flotation feed from the coarser sizes of coal treated in the main part of the preparation plant.

The flotation plants in Britain are, on an average, smaller in capacity than in this country, but they are far more numerous. As already noted, there were 43 froth-flotation plants in Britain in 1950 with an average capacity of a little over 11 tons per hour per plant. This is a rather small capacity, compared with plants now in operation and under construction in this country, a fact no doubt due to the much greater tons-per-hour output of run-of-mine coal at the mines where froth flotation is used in this country, which necessitates the treatment of larger tonnages of the froth flotation size.

An outstanding feature of British froth-flotation practice is that the closed-circuit system is being adopted quite generally. With this system, no slurry water is wasted, and the filtrate from vacuum filtering of the floated coal and the overflow from the settling of the flocculated flotation tailings are returned to the main washery circuit and, in some cases, partly to the flotation circuit. The flotation tailings after addition of flocculating reagents are generally run to Dorr-type thickeners for settling. The settlings are withdrawn from the bottom of the thickeners and disposed of either into lagoons or on the refuse dumps, the overflow being returned to the circuit. The flocculating reagents commonly used are Dryfloc or Unifloc made by the Unifloc Co., Ltd., in Swansea, Wales, or ferrous sulfate and starch. The quantity required ranges from 0.5 pound to as much as 2.0 pound per 1,000 gallons of tailings to be treated.

In British plants, shaking screens for dewatering washed coal are used very extensively, and they are advantageous in some respects over the commonly used settling tanks and dewatering bucket elevators in this country. The underflow from these screens is usually pumped into a settling cone, where the cone underflow can go either directly to the froth-flotation plant or be dewatered again on a finer screen, the final screen underflow going to flotation. By drawing a sufficient volume out of the bottom of the cone, enough of the extremely fine

Digitized by Google Original from THE OHIO STATE UNIVERSITY

material, say minus 200 mesh, can be removed for flotation to prevent an excessive build-up of fine solids in the washery water. In other words, the amount of "fines" removed is easily controlled by varying the volume of withdrawal from the cone spigot.

With this system of continuous removal of enough slurry fines from the main washer circuit to prevent a build-up of solids in the water, it might be expected that the flotation feed would have a somewhat higher proportion of fines smaller than 200 mesh than is usual in this country, where the flotation feed is usually deslimed, with varying amounts of slurry water being disposed of to waste. Such a trend is indicated by the screen analyses of the flotation feeds in tables 3 to 8. One screen analysis shows only 2.5 percent minus 240 mesh, but this is either an unaccountable anomaly or due to the pneumatic aspiration of the run-of-mine coal. Through oversight it was not learned whether or not the aspirated dust was added back to the flotation feed in this plant, but it probably was not, and this could account for the apparent anomaly. At the other six plants, the end screens, which were not always 200 mesh, showed the following percentages: 16.9 percent minus 200 mesh; 12.4 percent minus 240 mesh; 22.9 percent minus 240 mesh; 25.2 percent minus 90 mesh; 47.2 percent minus 200 mesh; and 60.2 percent minus 200 mesh. These figures give an indication of the build-up of fines smaller than 200 mesh that would probably result from the use of closed circuits in American plants - that is, circuits in which the flotation feed would not be deslimed and in which no slurry water would go to waste.